WHAT IS CLAIMED IS:

1   1. A method for processing, by a node of a network, a message carrying at least

2   one network path determination constraint, the method comprising:

3   a) performing a constraint-based path determination to a next node

4   selected from a group of nodes consisting of

5   (i) an area border node,

6   (ii) an autonomous system gateway node,

7   (iii) a node that can process one of the at least one network path

8   determination constraint carried by the message which the present

9   node cannot, or will not, evaluate,

10   (iv) a specified loose-hop node, and

11   (v) a node to which constraint processing is delegated,

12   to generate a partial path; and

13   b) forwarding the message carrying the at least one network path

14   determination constraint to an adjacent downstream node on the partial

15   path, or to a delegated node that is able to carry out the path

16   determination.

1   2. The method of claim 1 wherein the path is a label-switched path.

1   3. The method of claim 1 wherein the message is a resource reservation

2   protocol PATH message.

1   4. The method of claim 1 wherein the at least one network path determination

2   constraint includes at least two constraints selected from a group of constraints

3   consisting of:

4   - link type

5   - minimum link bandwidth,

6   - minimum reservable link bandwidth,

7   - maximum current bandwidth reservation,

8   - maximum current bandwidth usage,

9   - link coloring,

10   - link administrative group,

11   - link delay,

12   - link media type,

13   - end-to-end path minimum bandwidth,

14   - end-to-end path maximum number of hops,

15   - end-to-end path minimum priority,

16   - optical link wavelength,

17   - optical link minimum signal to noise ratio,

18   - optical link maximum power dispersion,

19   - optical link transmission power,

20   - optical link receiver sensitivity,

21   - node type,

22   - minimum node throughput,

23   - node quality of service support, and

24   - node queuing type.

1   5. A method for processing, by a node of a network, a message carrying at least

2   one network path determination constraint, the method comprising:

3   a) performing a constraint-based path determination to a next node to

4   generate a partial path; and

5   b) forwarding the message carrying the at least one network path

6   determination constraint to an adjacent downstream node on the partial

7   path.

1   6. A network node comprising:

2   a) a path determination facility for performing a constraint-based path

3   determination to a next node to generate a partial path; and

4   b) a signaling facility for

5 i) receiving a message carrying at least one network path

6 determination constraint, and

7 ii) forwarding the message carrying the at least one network path

8 determination constraint to an adjacent downstream node on the

9 partial path.

1 7. The method of claim 1 wherein the at least one network path determination

2 constraint includes at least one constraint selected from a group of constraints

3 consisting of:

4 - node type,

5 - minimum node throughput,

6 - node quality of service support, and

7 - node queuing type.

1 8. The method of claim 1 wherein the at least one network path determination

2 constraint includes a list of at least one explicit node specified to be a part of the

3 path.

1 9. The method of claim 8 wherein the list of at least one explicit node specified to

2 be a part of the path identifies at least one of a strict-hop node and a loose-hop

3 node.

1 10. The method of claim 8 wherein the message forwarded to the adjacent

2 downstream node on the partial path includes an updated list, and

3 wherein the node maintains the initial instance of the list, as

4 received.

1 11. The method of claim 1 wherein each of the at least one network path

2 determination constraint is an executable instruction.

1 12. The method of claim 11 wherein each executable instruction includes:

2   - information about a first operand;

3   - information about a second operand; and

4   - an operation code.

1   13. The method of claim 12 wherein the operation code identifies an operation

2   selected from a group of operations consisting of:

3   - bit-wise AND;

4   - bit-wise OR;

5   - bit-wise XOR;

6   - bit-wise equality;

7   - bit-wise inversion;

8   - Boolean AND;

9   - Boolean OR; and

10   - Boolean negation.

1   14. The method of claim 12 wherein the information about either of the first

2   operand or the second operand is a pointer to a register.

1   15. The method of claim 14 wherein the register is a register which contains a

2   link attribute.

1   16. The method of claim 14 wherein the register is a read-only register.

1   17. The method of claim 1 further comprising:

2   - generating a list which specifies nodes on the partial path as strict hop

3   nodes; and

4   - forwarding the list to an adjacent downstream node on the partial path.

1   18. A method for processing, by a node of a network, a message carrying at

2   least one network path determination constraint, the method comprising:

3   a) determining whether the node is a tail-end node, a head-end node, or

4   an intermediate node of the path;

5   b) if it is determined that the node is a tail-end node and each of the at

6   least on network path determination constraint has been satisfied, then

7   signaling back to an upstream node of the path that the path is OK;

8   c) if it is determined that the node is one of a head-end node and an

9   intermediate node, then

10   i) determining whether (a) a strict-hop node is specified as a next

11   node of an explicit path constraint, (b) a loose-hop node is specified

12   as a next node of an explicit path constraint, or (c) no node is

13   specified as an explicit path constraint,

14   ii) if a strict-hop node is specified as a next node of an explicit path

15   constraint, then

16   A) applying each of the at least one network path

17   determination constraint to an appropriate one of a link

18   between the node and the strict-hop node, the strict-hop

19   node, and the partial path defined,

20   B) if each of the at least one constraint is satisfied, then

21   forwarding a message carrying the at least one network path

22   determination constraint to the strict-hop node, and

23   C) if any one of the at least one constraint was not satisfied,

24   then signaling a path error back to an upstream node,

25   iii) if one of (a) a loose hop node is specified as a next node of an

26   explicit path constraint or (b) no node is specified as an explicit path

27   constraint, then

28   A) performing a constraint-based path determination to a

29   next node selected from a group of nodes consisting of

30   (1) an area border node,

31   (2) an autonomous system gateway node,

32   (3) a node that can process one of the at least one

33   network path determination constraint carried by the

34   message which the present node cannot, or is

35   unwilling to, evaluate,

36   (4) a specified loose-hop node, and

37   (5) a node to which constraint processing is

38   delegated,

39   to generate a partial path, and

40   B)   forwarding the message carrying the at least one

41   network path determination constraint to an adjacent

42   downstream node on the partial path.

1   19. The method of claim 18 wherein the upstream node is the head-end node.

1   20. A machine-readable medium having stored thereon at least one network

2   path determination constraint as an executable instruction, each executable

3   instruction comprising:

4   - information concerning a first operand;

5   - information concerning a second operand; and

6   -   an operation code.

1   21. The machine-readable medium of claim 20 wherein the operation code

2   denotes an operation selected from a group of operations consisting of:

3   - bit-wise AND;

4   - bit-wise OR;

5   - bit-wise XOR;

6   - bit-wise equality;

7   - bit-wise inversion;

8   - Boolean AND;

9   - Boolean OR; and

10   - Boolean negation.

1   22. The machine-readable medium of claim 20 wherein the information

2   concerning either of the first operand or the second operand is a pointer to a

3   register.

1   23. The machine-readable medium of claim 22 wherein the register is a register

2   that contains a link attribute.

1   24. The machine-readable medium of claim 22 wherein the link attribute is

2   selected from a group of link attributes consisting of:

3   - link type;

4   - maximum link bandwidth;

5   - maximum reservable link bandwidth;

6   - current bandwidth reservation;

7   - current bandwidth usage;

8   - link coloring;

9   - link administrative group;

10   - link delay;

11   - link media type;

12   - optical link wavelength;

13   - optical link minimum signal to noise ratio;

14   - optical link maximum power dispersion;

15   - optical link transmission power; and

16   - optical link receiver sensitivity.

1   25. The machine-readable medium of claim 22 wherein the register is a register

2   that contains a node attribute.

1   26. The machine-readable medium of claim 25 wherein the node attribute is

2   selected from a group of node attributes consisting of:

3   - node type;

4   - minimum node throughput;

5   - node quality of service support; and

6   - node queuing type.

1   27. The machine-readable medium of claim 20 having further stored thereon at

2   least one network path determination constraint as a list of at least one explicit

3   node that is specified to be a part of the network path.

1   28. The machine-readable medium of claim 27 wherein the at least one explicit

2   node is one of a loose-hop node and a strict-hop node.

1   29. A network node comprising:

2   a) a plurality of registers including attribute registers, the attribute

3   registers storing attributes of links in the network; and

4   b) a machine-readable medium having stored thereon at least one

5   network path determination constraint as an executable instruction, each

6   executable instruction including

7   i) a first operand pointer,

8   ii) a second operand pointer, and

9   iii) an operation code,

10   wherein at least one of the first and second operand pointers

11   points to one of the attribute registers.

1   30. The network node of claim 29 wherein the plurality of registers further

2   includes general purpose registers,

3   wherein each of the attribute registers is a read-only register, and

4   wherein each of the general purpose registers is read/write register.

1   31. The network node of claim 29 wherein the machine-readable medium also

2   has stored thereon at least one network path determination constraint as a list of

3   at least one explicit node that is specified to be a part of the network path.

1   32. The network node of claim 31 wherein the at least one explicitly specified

2   node is one of a loose-hop node and a strict-hop node.

1   33. The network node of claim 29 wherein the plurality of registers further

2   include accumulation registers storing cumulative attributes of a path.

1   34. A machine-readable medium having stored thereon:

2   a) an executable instruction encoding at least one network path

3   determination constraint; and

4   b) a list of at least one explicit node specified to be a part of the path.

1   35. The machine-readable medium of claim 34 wherein the executable

2   instruction includes:

3   - information concerning a first operand;

4   - information concerning a second operand; and

5   - an operation code.

1   36. A method for processing, by a node of a network, a message carrying at

2   least one network path determination constraint, the method comprising:

3   a) if the tail-end node of the path is in a part of the network, the topology

4   of which is not known by the node, then performing a constraint-based

5   path determination to a next node selected from a group of nodes

6   consisting of

7   (i) an area border node, and

8   (ii) an autonomous system gateway node,

9   to generate a partial path; and

10   b) forwarding the message carrying the at least one network path

11   determination constraint to an adjacent downstream node on the partial

12   path.

● ●

1   37. A method for processing, by a node of a network, a message carrying at

2   least one network path determination constraint, the method comprising:

3   a) if a next node specified in a list of explicit nodes is a loose-hop node,

4   then performing a constraint-based path determination to the next

5   loose-hop node to generate a partial path; and

6   b) forwarding the message carrying the at least one network path

7   determination constraint to an adjacent downstream node on the partial

8   path.

1   38. A method for processing, by a node of a network, a message carrying at

2   least one network path determination constraint, the method comprising:

3   a) if the node cannot process any one of the at least one network path

4   determination constraint, performing a constraint-based path

5   determination to a node that can process that one of the at least one

6   network path determination constraint, to generate a partial path; and

7   b) forwarding the message carrying the at least one network path

8   determination constraint to an adjacent downstream node on the partial

9   path.

1   39. A method for processing, by a node of a network, a message carrying at

2   least one network path determination constraint, the method comprising:

3   a) if constraint processing has been delegated to another network

4   element, performing a constraint-based path determination to the other

5   network element to which constraint processing has been delegated to

6   generate a partial path; and

7   b) forwarding the message carrying the at least one network path

8   determination constraint to an adjacent downstream node on the partial

9   path.

1   40. In a network node, a routing facility, the routing facility comprising:

2   a) a process for generating a traffic engineering database;

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3   b) a traffic engineering database generated by the processing for

4   generating;

5   c) a signaling facility; and

6   d) a constraint-based path determination facility for determining at

7   least a part of a path based on

8   i) contents of the traffic engineering database, and

9   ii) at least one path constraint received from the signaling

10   facility,

11   wherein, if the routing facility cannot determine a complete

12   constraint-based path to a specified tail-end node, then the constraint-based

13   path determination facility performs a constraint-based path determination to

14   a next node selected from a group of nodes consisting of

15   - an area border node,

16   - an autonomous system gateway node,

17   - a node that can process one of the at least one network path

18   determination constraint carried by the message which cannot be

19   evaluated by the present node,

20   - a specified loose-hop node, and

21   - a node to which constraint processing is delegated,

22   to generate a partial path, and

23   the signaling facility forwards a message carrying the at least one path

24   constraint to an adjacent downstream node on the partial path.

1   41. The routing facility of claim 40 wherein the path is a label-switched path.

1   42. A method of establishing a path from a first node to a second node in a

2   network, the method comprising:

3   a) computing a first portion of the path from the first node to a first

4   intermediary node, subject to a set of at least one constraint;

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5   b) generating a message that includes information relating to the set

6   of constraints; and

7   c) transmitting the message to a down-stream node on the first portion

8   of the path.

1   43. The method according to claim 42, wherein the path is a label-switched

2   path.

1   44. The method according to claim 42, wherein the act of generating includes

2   generating a message that includes instructions for determining additional

3   portions of the path in which the set of at least one constraint is met.

1   45. The method according to claim 42, wherein the act of generating includes

2   generating a message that includes a set of instructions for determining a

3   second portion of the path from the first intermediary node to the second node

4   subject to the set of at least one constraint.

1   46. The method according to claim 42, wherein the act of generating includes

2   generating a message that includes a set of instructions for determining a

3   second portion of the path from the first intermediary node to a second

4   intermediary node subject to the set of at least one constraint.

1   47. A method of establishing a path from a first node to a second node in a

2   network, the method comprising:

3   a) receiving, at a first intermediary node, a message including

4   information defining a first portion of the path and information relating

5   to a set of at least one constraint;

6   b) computing, at the first intermediary node, a second portion of the

7   path subject to the information relating to the set of at least one

8   constraint.

1   48. The method according to claim 47, wherein the act of computing is

2   performed if the first intermediary node is the last node in the first portion of

3   the path.

1   49. The method according to claim 47, wherein the act of computing includes

2   computing additional portions of the path subject to the set of at least one

3   constraint.

1   50. The method according to claim 47, wherein the act of computing includes

2   computing a second portion of the path from the first intermediary node to the

3   second node.

1   51. The method according to claim 47, wherein the act of computing includes

2   computing a second portion of the path from the first intermediary node to a

3   second intermediary node.

1   52. A method of establishing a path from a first node to a second node in a

2   network, the method comprising:

3   a) receiving, at a first intermediary node, a message including

4   information defining a first portion of the path and information relating

5   to a set of at least one constraint; and

6   b) if the first intermediary node is not the last node in the first portion

7   of the path, transmitting, from the first intermediary node to the next

8   downstream node in the first portion of the path, at least a part of the

9   received message.

1   53. A method of establishing a path from a first node to a second node in a
2   network, the method comprising:
3   a) receiving, at a first intermediary node in a first portion of the path, a
4   message that includes information relating to a set of at least one
5   constraint; and
6   b) determining whether a link from the first intermediary node to the
7   next node specified in the first portion of the path satisfies the set of at
8   least one constraint.

1   54. The method of claim 53, further comprising:
2   c) if the link from the first intermediary node to the next node specified
3   in the first portion of the path is determined to satisfy the set of at least
4   one constraint, then transmitting the received message to the next
5   node.

1   55. The method of claim 53, further comprising
2   c) if the link from the first intermediary node to the next node specified
3   in the first portion of the path is determined not to satisfy the set of at
4   least one constraint, then transmitting an error message back to the
5   source node.

1   56. A method of processing a message that includes information defining a
2   first portion of a path from a first node to a second node in a network and
3   information relating to a set of at least one constraint for establishing the path,
4   the method comprising:
5   a) determining, at a receiving node that receives the message,
6   whether the receiving node comprises the second node or an
7   intermediary node in the path;

8 b) if the receiving node is determined to be the second node, then

9 generating, at the receiving node, a message to be sent to the first

10 node; and

11 c) if the receiving node is determined to be an intermediary node in

12 the path, then:

13   i) determining whether the message specifies at least one of a

14   strict-hop node and a loose-hop node;

15   ii) if the message specifies a strict-hop node, then forwarding the

16   message to the strict-hop node on a link in which the set of

17   constraints are met;

18   iii) if the message does not specify a strict-hop node, but specifies

19   a loose-hop node, then computing paths from the receiving node to

20   the loose-hop node subject to the set of at least one constraint and

21   selecting one of the computed paths on which to transmit the

22   message; and

23   iv) if the message does not specify either a strict-hop node or a

24   loose-hop node, then computing paths from the receiving node to

25   either the second node or an intermediary node subject to the set of

26   at least one constraint and selecting one of the computed paths on

27   which to transmit the message.

1 57. An instruction embodied on a medium used to determine whether a path

2 through a network to a destination node meets a constraint, the instruction

3 comprising:

4   a) a first operand specifying a memory location in which a value for an

5   attribute of a network node or link is stored;

6   b) a second operand representing a constraint value for the attribute;

7   c) a code specifying an operation to be performed on the first operand

8   and second operand; and

9   d) a result portion specifying a memory location in which a result of the

10   operation performed on the first operand and second operand is

11   stored.

1   58. A message embodied on a medium used to establish a path through a

2   network from a first node to a second node, the message comprising:

3   a) a set of at least one constraint for defining the path;

4   b) a set of at least one instruction for specifying operations to be

5   performed on the set of at least one constraint; and

6   c) information relating to at least one previously computed portion of

7   the path.

1   59. The message according to claim 58, further comprising:

2   d) information relating to an accumulated value for at least one of the

3   at least one constraint.

1   60. A table embodied on a medium, the table comprising:

2   a) a first entry representing a first attribute of a node or link connected

3   to the node;

4   b) a second entry representing an accumulated value for a second

5   attribute of a node or link connected to the node; and

6   c) a third entry storing a result of a specified operation performed on

7   one of the first entry and the second entry.

1   61. A node in a network, the node comprising:

2   a) a first portion of memory storing attributes of nodes or links in the

3   network;

4   b) a second portion of memory storing network-path constraints;

5 c) a third portion of memory storing instructions for performing

6 operations on the stored attributes and the stored constraints; and

7 d) a processor for executing the instructions stored in the third portion

8 of memory and computing a path in the network based on results of

9 the executed instructions.

1 62. A node of a network, the node comprising:

2 a) an input for accepting a message carrying at least one network path

3 determination constraint;

4 b) a path determination facility for, if the node cannot process any one

5 of the at least one network path determination constraint, performing a

6 constraint-based path determination to a node that can process that

7 one of the at least one network path determination constraint, to

8 generate a partial path; and

9 c) a signaling facility for forwarding the message carrying the at least

10 one network path determination constraint to an adjacent downstream

11 node on the partial path.

1 63. A node of a network, the node comprising:

2 a) an input for accepting a message carrying at least one network path

3 determination constraint;

4 b) a path determination facility for, if constraint processing has been

5 delegated to another network element, performing a constraint-based

6 path determination to the other network element to which constraint

7 processing has been delegated to generate a partial path; and

8 c) a signaling facility for forwarding the message carrying the at least

9 one network path determination constraint to an adjacent downstream

10 node on the partial path.

1   64. A network node comprising:

2   a) a path determination facility for determining a first portion of a path

3   from the network node to a first intermediary node, subject to a set of

4   at least one constraint; and

5   b) a signaling facility for

6   i) generating a message that includes information relating to the

7   set of at least one constraint, and

8   ii) transmitting the message to a downstream node on the first

9   portion of the path.

1   65. A network node in a path between a first node and a second node, the

2   network node comprising:

3   a) an input for receiving a message including information defining a

4   first portion of the path and information relating to a set of at least one

5   constraint; and

6   b) a signaling facility for, if the network node is not the last node in the

7   first portion of the path, transmitting to the next downstream node in

8   the first portion of the path, at least a part of the received message.

1   66. A network node in a first portion of a path between a first node and a

2   second node, the network node comprising:

3   a) receiving a message that includes information relating to a set of at

4   least one constraint; and

5   b) means for determining whether a link from the network node to a

6   next node specified in the first portion of the path satisfies the set of at

7   least one constraint.

1   67. The network node of claim 66 further comprising:

2   c) a signaling facility for, if the link from the network node to the next

3   node specified in the first portion of the path is determined to satisfy

4   the set of at least one constraint, transmitting the received message to

5   the next node.

1   68. The network node of claim 66 further comprising

2   c) a signaling facility for, if the link from the network node to the next

3   node specified in the first portion of the path is determined not to

4   satisfy the set of at least one constraint, then transmitting an error

5   message back to the first node.

1   69. A network node comprising:

2   a) an input for accepting a message that includes information defining a

3   first portion of a path from a first node to a second node in a network and

4   information relating to a set of at least one constraint for establishing the

5   path;

6   b) means for determining whether the network node comprises the

7   second node or an intermediary node in the path; and

8   c) a signaling facility for

9   i) if the network node is determined to be the second node,

10   generating a message to be sent to the first node, and

11   ii) if the network node is determined to be an intermediary node in

12   the path,

13   A) determining whether the message specifies at least one

14   of a strict-hop node and a loose-hop node;

15   B) if the message specifies a strict-hop node, forwarding the

16   message to the strict-hop node on a link in which the set of

17   constraints are met;

18   C) if the message does not specify a strict-hop node, but

19   specifies a loose-hop node, computing paths from the

20   receiving node to the loose-hop node subject to the set of at

21   least one constraint and selecting one of the computed paths

22   on which to transmit the message; and

23   D) if the message does not specify either a strict-hop node

24   or a loose-hop node, then computing paths from the

25   receiving node to either the second node or an intermediary

26   node subject to the set of at least one constraint and

27   selecting one of the computed paths on which to transmit the

28   message.

1   70. A method for processing, by a node of a network, a message carrying at

2   least one network path determination constraint, the method comprising:

3   a) determining whether to delegate constraint processing to another

4   device; and

5   b) if it has been determined that constraint processing has been

6   delegated to another network element, forwarding the message carrying

7   the at least one network path determination constraint to the other device.